Final Report for NAG5-2739

Two-D Representation of Three-D Modeling of Atmospheric Effects of Aircraft

Our principal accomplishments during the period of this research grant were as follows:

(1) Development of 2-D Transport Coefficients from a 3-D GCM;

(2) Comparison of various 2-D Treatments of Temperature; Asymmetries for Use in 2-D Models;

(3) Development and Testing of Convective Flux Formulation from a GCM for Use in a 2-D Model; and

(4) Investigation of Bromine Balance in the Upper Troposphere and Lower Stratosphere.

In the following, each of these topics will be treated in more detail.

(1) Development of 2-D Transport Coefficients from a 3-D GCM

The principal results of this work are found in Yudin et al. (1999), which has been submitted for publication in the *Journal of the Atmospheric Sciences*. This paper compares the evaluations of K_{yy} using the methods of Plumb and Mahlman (1987), PM87, with those of Newman et al. (1986) and Garcia (1991). It is concluded that a variation of PM87 in which the derived K_{yy} and K_{zz}, together with the derived residual circulation, gives reasonable results. This is shown by comparing the zonal mean distributions of CH_4 and N_2O from a 3-D model with the 2-D distributions derived using a 2-D model using the transport coefficients from the 3-D model. These transport coefficients have been used in the SUNY-SPb model in the 1998 HSCT Assessment.

(2) Comparison of various 2-D Treatments of Temperature; Asymmetries for Use in 2-D Models

The principal results of this work are found in Smyshlyaev et al. (1998). In this work, the treatment of temperature asymmetries using the methods of Considine et al. (1994) and De Rudder et al. (1996) are compared. It is found that the "best" results are found using a variation of De Rudder et al.'s (1996) treatment where the amplitude and phase information of planetary waves with zonal wavenumbers 1-3 are used to derive effective heterogeneous chemical reaction rates.

(3) Development and Testing of Convective Flux Formulation from a GCM for Use in a 2-D Model

The principal results of this work are found in Dvortsov et al. (1998). In this paper, methods are used to obtain 2-D transports from the NCAR CCM3 model convective transports. A 2-D model using the large-scale transports from Yudin et al. (1999) and our derived convective transports are used to model Radon-222. It is shown that this 2-D model obtains results for Radon-222 that are in very good agreement with those using the 3-D dynamics.

(4) Investigation of Bromine Balance in the Upper Troposphere and Lower Stratosphere

The principal results of this work are found in Dvortsov et al. (1999), which has been submitted for publication to *Geophysical Research Letters*. In this paper, the SUNY-SPb 2-D model is used, in tandem with the NCAR MATCH 3-D transport model driven by the CCM3 dynamics, to examine the contributions of short-lived bromocarbons to the stratospheric inorganic bromine (Br_y) budget. Previously, such species have been neglected in stratospheric modeling since it was assumed that their contributions were negligibly small. At variance with that picture, we found that bromoform is likely responsible for more Br_y than all other known sources in the mid-latitude lower stratosphere. This would likely increase the ozone loss in models from what has been previously estimated and give rise to more geographic variability in ozone loss rates than has previously been considered.

Other important outputs of this funded research have been a Ph.D. dissertation by Victor Dvortsov (1998) and photochemical and chemistry benchmark calculations for Stolarski et al. (1995).

References

Considine, D. B., A. R. Douglass, and C. H. Jackman, 1994: Effects of polar stratospheric cloud parameterization on ozone depletion due to stratospheric aircraft in a two-dimensional model. *J. Geophys. Res.*, **99**, 18879-18894.

De Rudder, A., N. Larsen, X. Tie, C. Granier, and G. Brasseur, 1996: Model study of polar stratospheric clouds and their effect on stratospheric ozone. *J. Geophys. Res.*, **101**, 12567-12574.

Dvortsov, V. L., 1998: Atmospheric distribution of 222 Radon and bromine species as simulated with 3-D and 2-D transport with convection. Ph.D. Dissertation, State University of New York at Stony Brook.

Dvortsov, V. L., M. A. Geller, and V. A. Yudin, 1998: Parameterization of the convective transport in a two-dimensional chemistry-transport model and its validation with radon 222 and other tracer simulations. *J. Geophys. Res.*, **103**, 22047-22062.

Dvortsov, V. L., M. A. Geller, S. Solomon, S. M. Schauffler, E. L. Atlas, and D. R. Blake, 1999: Reactive halogens in the ozone depletion region: a new approach. Submitted to *Geophys. Res. Lett.*

Garcia, R. R., 1991: Parameterization of planetary wave breaking in the middle stratosphere. *J. Atmos. Sci.*, **48**, 1405-1419.

Newman, P. A., M. R. Schoeberl, and R. A. Plumb, 1986: Horizontal mixing coefficients for two-dimensional chemical models calculated from National Meteorological Center data. *J. Geophys. Res.*, **91**, 7919-7924.

Plumb, R. A., and J. D. Mahlman, 1987: The zonally averaged transport characteristics of the GFDL general circulation/tracer model. *J. Atmos. Sci.*, **44**, 298-327.

Smyshlyaev, S. P., V. L. Dvortsov, M. A. Geller, and V. A. Yudin, 1998: A two-dimensional model with input parameters from a general circulation model: Ozone sensitivity to different formulations for the longitudinal temperature variation. *J. Geophys. Res.*, **103**, 28373-28387.

Stolarski, R. S., S. L. Baughcum, W. H. Brune, A. R. Douglass, D. W. Fahey, R. R. Friedl, S. C. Liu, R. A. Plumb, L. R. Poole, H. L. Wesoky, and D. R. Worsnop, 1995: *1995 Scientific Assessment of the Atmospheric Effect of Stratospheric Aircraft*, NASA Reference Publication 1381, Washington, DC.

Yudin, V. A., S. P. Smyshlyaev, M. A. Geller, and V. Dvortsov, 1999: Transport diagnostics of GCMs and implications for 2-D chemistry-transport modeling of the troposphere and stratosphere. Submitted to *J. Atmos. Sci.*